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<b>(21) International Application Number:</b> PCT/US82/01670 <b>(22) International Filing Date:</b> 30 November 1982 (30.11.82)  <b>(31) Priority Application Number:</b> 327,538 <b>(32) Priority Date:</b> 4 December 1981 (04.12.81) <b>(33) Priority Country:</b> US  <b>(71) Applicant:</b> UNITED STATES OF AMERICA as represented by SECRETARY, DEPARTMENT OF COMMERCE [US/US]; Springfield, VA, (US).  <b>(72) Inventors:</b> MACKENZIE, John, D. ; 2456 Arbutus Drive, Los Angeles, CA 90049 (US). HORIUCHI, Tetsuro ; 4127 McLaughlin #6, Los Angeles, CA 90056 (US).  <b>(74) Agents:</b> SEARS, Mary, Helen et al.; Irons and Sears, 1785 Massachusetts Avenue, N.W., Washington, DC 20036 (US).		<b>(81) Designated States:</b> BE (European patent), DE (European patent), FR (European patent), GB (European patent), JP, NL (European patent), SE (European patent).  <b>Published</b> <i>With international search report.</i>
<b>(54) Title:</b> ALKALI-RESISTANT GLASS FIBERS  <b>(57) Abstract</b>  Alkali-resistant glass fibers comprising about 30 to 60 percent SiO <sub>2</sub> , 15 to 20 percent Al <sub>2</sub> O <sub>3</sub> , 20 to 30 percent CaO, and 1 to 10 percent Fe <sub>2</sub> O <sub>3</sub> . The fibers may be prepared from inexpensive materials such as slate and limestone.		

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ALKALI-RESISTANT GLASS FIBERS

This invention relates to novel alkali-resistant glass fibers, and their preparation. The fibers find particular use in strengthening cement and concrete products, and may find extensive use as substitutes for asbestos in such products.

Asbestos fibers have long been used to strengthen cement and concrete products. However, since the recognition of the toxicity of asbestos there have been many attempts to develop fibers to replace it. One of the most important properties of fibers for use in cement and concrete products is resistance to chemical attack by the alkali in the cement mixtures. Because the diameter of the fibers is usually very small, e.g., about 2 to 20 micrometers, a relatively small degree of attack can cause a large decrease in mechanical strength.

The most promising substitute for asbestos to date has been zirconia-containing glass fibers. Although these fibers are fairly resistive to alkali attack, they are expensive and difficult to fabricate because of the very high melting temperatures required. Accordingly, there is a need for a fiber that is resistant to alkali attack, as well as being relatively easy and cheap to fabricate.

It has now been found, according to the present invention, that a new family of zirconia-free glass fibers, having the compositions set forth below, are highly resistant to alkali attack. In addition, these fibers are readily prepared from raw materials that are inexpensive and readily available. The fibers of the invention have the following approximate compositions, in percent by weight:



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$\text{SiO}_2$	30-60%
$\text{Al}_2\text{O}_3$	15-20%
$\text{CaO}$	20-30%
$\text{Fe}_2\text{O}_3$	1-10%

It has also been found that about 1 to 7% of  $\text{MgO}$ , 2 to 8% of  $\text{K}_2\text{O}$  or 1 to 5% of  $\text{Na}_2\text{O}$  can be included in the above compositions without adversely affecting the alkali resistance of the fibers. The fibers are prepared by means of procedures conventionally employed in preparation of glass fibers, i.e., melting of the appropriate admixture of raw materials, followed by drawing or spinning to form the fibers.

The above compositions can be readily, and inexpensively, formed from mixtures of naturally occurring slate and limestone. Suitable raw materials are not, however, limited to freshly mined slate and limestone, but may include waste slate and waste marble, e.g., materials left over from mechanical working of slate and marble. In addition, other materials such as basalt may be used. The raw materials are initially ground, or otherwise reduced, to a suitable particle size, e.g., about 50 to 200 mesh, and are then admixed and melted in suitable refractory vessels such as pots or crucibles of refractory materials such as chromite, alumina, platinum, etc. Suitable melt temperatures are obtained by conventional means, such as electric furnaces or gas furnaces, and will generally range from about 1300 to 1400°C, with the optimum depending on various factors such as the specific composition of the melt, raw materials employed, and desired properties of the product fibers. The admixture is desirably maintained



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at the melt temperature for a period of about 3 to 5 hours to ensure complete fusion of the ingredients.

The molten mixture is then cooled to a temperature, generally about 1100 to 1250°C, suitable for working, and fibers are formed by conventional means such as drawing at high speed through a fine orifice, or by spinning to form a glass wool. Conventional means, such as contacting with screens of appropriate mesh size, are also employed to reduce the fibers to suitable lengths. Optimum diameters and lengths of the fibers will vary with the specific use; however, diameters of about 8 to 12 microns and lengths of about 1/8 to 1/2 inch are generally most suitable for use in cement and concrete products. Fibers thus prepared have been found to have tensile strengths of about 80,000 to 150,000 psi and densities of about 2.75 to 2.95 gm/cc. Alkali resistance of the fibers has been found to be much superior to Pyrex glass and as good as commercially available alkali-resistant glasses.

The invention will be more specifically illustrated by the following example.

#### Example

Glass fibers were prepared from three mixtures of Vermont slate and limestone, and were compared with fibers of a commercially available alkali-resistant (AR) glass and pyrex glass. The mixtures of slate and limestone consisted, respectively, of 40% slate and 60% limestone, 50% each of slate and limestone, and 60% slate and 40% limestone. Chemical compositions, in weight %, of the slate-limestone mixtures, as well as the AR and pyrex glasses, are given in Table 1.



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Table ISlate-limestone glass

<u>Composition</u>	<u>40/60</u>	<u>50/50</u>	<u>60/40</u>	<u>AR glass</u>	<u>Pyrex</u>
SiO <sub>2</sub>		38.6		61.0	80.9
ZrO <sub>2</sub>				21.0	
B <sub>2</sub> O <sub>3</sub>					12.7
Al <sub>2</sub> O <sub>3</sub>		17.6		1.5	2.3
Fe <sub>2</sub> O <sub>3</sub>		4.72			0.03
CaO		28.0		3.0	
MgO		2.65			
Na <sub>2</sub> O		2.16		16.5	4.0
K <sub>2</sub> O		2.76			0.04

\* Central Glass Co., U.S. Patent No. 4,066,465

The slate and limestone were ground to a particle size of 100 mesh and thoroughly mixed by means of a ball-mill. The mixtures were then melted at 1350°C in air, and were maintained at this temperature for a period of about 3-5 hrs. The melt was then cooled to 1150°C, and fibers of a diameter of 20 microns were formed by drawing. The fibers were reduced to lengths of 1/2 to 1 inch by means of mechanical cutters. These fibers, and similar fibers of AR and pyrex glasses, were then tested for



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alkali resistance by reaction in 5% NaOH solution at 90°C for 4 hours. Results of the tests, as well as properties of the glasses are shown in Table 2. It is evident from the data of the table that the glasses of the invention are much superior to Pyrex and are as good as commercially available AR glasses.

Table 2Slate-limestone glass

<u>Properties</u>	<u>40/60</u>	<u>50/50</u>	<u>60/40</u>	<u>AR glass</u>	<u>Pyrex</u>
Density (g/cm <sup>3</sup> )	2.76	2.82	2.92	-	2.23
Melting Temp. (°C)	1300	1350	1400	1500	1400
Fiber Drawing Temp. (°C)	1150	1200	1250	1350	-
Alkali Resistance,	0.80	0.36	0.13	0.37	6.47



we claim:

1. Alkali-resistant glass fibers comprising, in percent by weight, about 30 to 60 percent  $\text{SiO}_2$ , about 15 to 20 percent  $\text{Al}_2\text{O}_3$ , about 20 to 30 percent  $\text{CaO}$ , and about 1 to 10 percent  $\text{Fe}_2\text{O}_3$ .

2. Fibers of claim 1 also containing about 1 to 7 percent  $\text{MgO}$ , about 2 to 8 percent  $\text{K}_2\text{O}$ , and/or about 1 to 5 percent  $\text{Na}_2\text{O}$ .

3. A method for preparation of the glass fibers of claims 1 or 2 comprising admixing slate and limestone, melting the admixture at a temperature of about 1300 to 1400°C, lowering the melt temperature to about 1100 to 1250°C, and forming fibers therefrom.

4. A method for strengthening cement and concrete products by incorporating therein, prior to the curing of said cement and concrete products, alkali-resistant glass fibers of the composition of claim 1.

5. A method for strengthening cement and concrete products by incorporating therein, prior to the curing of said cement and concrete products, alkali-resistant glass fibers of the composition of





claim 2.

6. Alkali-resistant glass fiber reinforced cement and concrete products comprising a cementitious matrix and reinforcing alkali-resistant glass fibers having the composition of claim 1.

7. Alkali-resistant glass fiber reinforced cement and concrete products comprising a cementitious matrix and reinforcing alkali-resistant glass fibers having the composition of claim 2.



# INTERNATIONAL SEARCH REPORT

International Application No PCT/US82/01670

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC <sup>3</sup> C04B 7/02		
US 428/364, 703; 106/99		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched *		
Classification System	Classification Symbols	
US	106/99 428/364, 703	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched *		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <sup>14</sup>		
Category *	Citation of Document, <sup>15</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No. <sup>18</sup>
Y	US, A, 3,887,386 Published 03 June 1975, National Research and Development Corporation	1-6
Y	US, A, 4,002,482 Published 11 January 1977, JENAer Glaswerk Schott & Gen.	1-6
Y	US, A, 4,095,986 Published 20 June 1978, Director-General, agency of Industrial Science and Technology	1-6
Y	US, A, 4,153,439 Published 08 May 1979, Rockwool Aktiebolaget	1-6
X	US, A, 4,205,992 Published 03 June 1980, See column 1, lines 33-51 and column 2, line 38 et seq., Rockwool Aktiebolaget	1-6
<p>* Special categories of cited documents: <sup>15</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"Δ" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search <sup>3</sup>	Date of Mailing of this International Search Report <sup>3</sup>	
02 February 1983	15 FEB 1983	
International Searching Authority <sup>1</sup>	Signature of Authorized Officer <sup>10</sup>	
US	W. J. VanBalen	